Portland Cement Concrete Field Testing Procedures **Construction Inspector's Training Manual**

January 2005

Washington State
Department of Transportation

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Washington State Department of Transportation
Environmental and Engineering Programs
Construction Office

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Part 1

Introduction

Goals

This course is designed to provide you with the skills to recognize and properly test Portland cement concrete.

Acceptance testing will be performed by the state in accordance with WSDOT Standard Test Methods as set forth in the WSDOT Laboratory Manual. WSDOT Standard Test Methods to be used with this specification are:

- FOP WAQTC TM 2 Sampling Freshly Mixed Concrete
- FOP WSDOT Test Method No. 716 Random Sampling
- FOP AASHTO T-309 Temperature of Freshly Mixed Portland Cement Concrete
- FOP AASHTO T-119 Method of Test for Slump of Hydraulic Cement Concrete
- FOP AASHTO T-152 Air Content of Freshly Mixed Concrete by the Pressure Method
- FOP AASHTO T-23 Making and Curing Concrete Test Specimens in the Field
- FOP ASTM C-805 Rebound Number of Hardened Concrete
- FOP ASTM C-939 Flow of Grout for Preplaced-Aggregate Concrete (Flow Cone Method)
- FOP WSDOT Test Method No. 813 Fabrication of 2-Inch Cube Specimens for Compressive Strength Testing of Grout and Mortars

What is Concrete?

In its simplest form, concrete is a mixture of paste and aggregates. The paste, composed of Portland cement and water, coats the surface of the fine and coarse aggregates. Through a chemical reaction called hydration, the paste hardens and gains strength to form the rock-like mass known as concrete. Within this process lies the key to a remarkable trait of concrete: it's plastic and malleable when newly mixed, strong and durable when hardened.

Aggregates (Standard Specification 9-03.1)

Aggregates are basically divided into two types: fine and coarse. Aggregate less than 3/8 inch is typically classified as fine aggregate. Aggregates typically make up about 60 percent to 75 percent of the total volume of concrete.

Aggregate used in concrete should be clean, well graded and resistant to abrasion and degradation. Aggregates containing porous materials should be avoided.

In general, smooth, round aggregate is used in concrete because it takes less water to produce a more workable mix.

Water (Standard Specification 9-25.1)

Any water that is potable (drinkable) and has no pronounced taste or odor may be used as mixing water for concrete. If the water has a pronounced odor, discoloration or other suspicious characteristics the Engineer may require the Contractor to provide test results in accordance with Standard Specification 9-25.1.

Flyash

Flyash is a material that forms cementious compounds when mixed with lime and water, it aids in the efficiency of concrete. See Pozzoloan Tech Bulletin in Appendix A.

Water Cement Ratio

Depending on a particular set of materials and conditions of curing, the quality of hardened concrete is determined by the amount of water used in relation to the amount of cementitious material. Without water the hydration process cannot start but, too much water can cause the strength to drop. This relationship is referred to as the water/cement ratio. The actual water cement ratio shall be determined from the certified proportions of water in the mix, adjusting for on the job additions, divided by the total weight of cementitous material. No water may be added after acceptance testing or after placement has begun, except for concrete used in slip forms.

Some advantages to using lower water content include:

- Increased compressive and flexural strength.
- Lower permeability thus increased water tightness and lower absorption.
- Increased resistance to weathering.
- Better bond between successive layers and between concrete and reinforcement.
- Less volume change from wetting and drying.
- Reduced shrinkage cracking tendencies.

Example

A truck arrives on the job site and the mix contains the following:

Flyash	725 lbs
Portland Cement	6,525 lbs
Water added at plant	210 gallons
Free moisture	25 gallons
Water added at job site	5 gallons

Total cementitious material is:	**725 + 6,525**	= **7,250 lbs**
Total water in mix is:	**210 + 25 + 5**	= **240 gallons**
Convert gallons of water to pounds;	**240 x 8.34**	= **2,001.6 lbs**

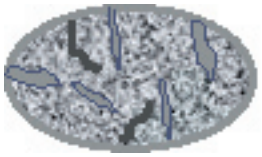
2,001.6 (gallons of water in pounds) divided by **7,250** (total cementitious material) = **0.28**.

0.28 is the water/cement ratio for this load.

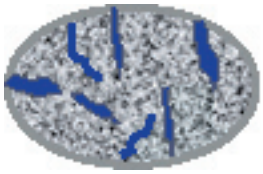
Total Water

Total water consists of: water added at the plant, water added on the job site and free moisture (which is the water associated with the aggregate). You can easily find the total water added at the plant from the concrete delivery ticket and you will be present if it is added at the jobsite, but how do you determine the amount of free moisture?

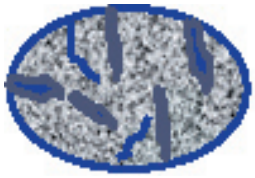
To understand free moisture you must first understand the three conditions of aggregate: Oven Dry, Saturated Surface Dry, and Saturated,. See the illustrations below for the description of each condition.



Oven Dried - Completely Dry



Saturated Surface Dry - Surface Dry
But still have moisture inside



Saturated - Interior and exterior moist,
The exterior moisture is Free Moisture

When aggregate is saturated, water sits on the surface this water is available to the concrete and must be calculated into the total water. To start the calculation you must first know the percent of moisture in both the course and fine aggregate. You will find these numbers on the concrete delivery ticket.

To calculate the weight of the water in the aggregate take the weight of the aggregate and divide it by one plus the percent of moisture

Example:

(Sand moisture) 10,500 lbs / 1.05 =10,000 lbs 10,500 lbs - 10,000 lbs = 500 lbs

(Gravel moisture) 18,100 lbs / 1.01 = 17,921 lbs 18,100 lbs - 17921 lbs = 179 lbs

Now you can calculate the water/cement ratio using the following information:

Example

Cementitious Material cement 6600 lbs

Total water	Wet Sand	10500 lbs (5% Free Moisture)	=	500 lbs
	Wet Gravel	18110 lbs(1% Free Moisture)	=	179 lbs
	H_2O Plant	254 gal * 8.34 lbs/gal	=	2,118 lbs
	H_2O Jobsite	5 gal * 8.34 lbs/gal	=	42 lbs
				2,839 lbs

Water/cement ratio **2,839 lbs / 6600 lbs = 0.43**

Air Entrained Concrete

Air entrainment is required for all concrete placed above the finish ground line. Air entrainment improves the concrete's resistance to freezing when exposed to water and deicing chemicals. Air-entrained concrete contains microscopic air cells that help relieve internal pressure on the concrete by providing tiny chambers for the expansion of water when it freezes. There are billions of bubbles present in 1 cubic yard of concrete.

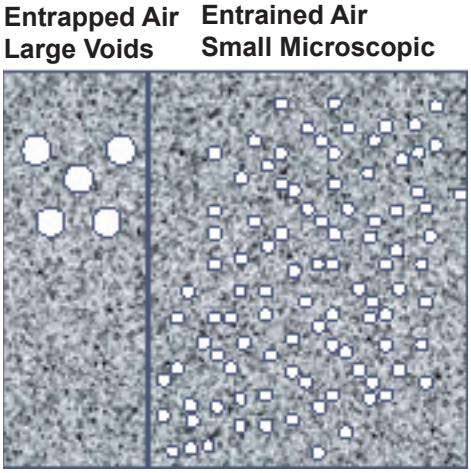
Air-entrained concrete is produced by introducing air-entraining admixtures into the mix.

Advantages

- Improved workability
- Reduced segregation
- Earlier finishing
- Less sand and about 10 percent less water
- Increased freeze-thaw resistance
- Improved-scaling resistance
- Improved water tightness

Disadvantages

- Reduced strength



Part 2

Mix Designs

Concrete Mix Design

A concrete mix design is a list of ingredients and their proportions used in a mix. A concrete mix design's purpose is to have economical mix proportions which complies with the contract specification and has adequate workability to be placed in it's final position on site.

The use of a mix design is to assure that the mix performs at the needed design specifications. Some things to look for in a mix design are:

- The minimum amount of cement specified in 6-02.3(2)A is used.
- The minimum amount of flyash is listed (if called for)
- The amount of flyash (if used) does not exceed 25 percent
- All aggregate conforms to standard specification 9-03.1
- Air entrainment is used where required.

A concrete mix design can be checked after the producer of the concrete has submitted it for approval. Per Standard Specification 6-02.3(2)A, the contractor shall provide a mix design in writing to the Engineer for all classes of concrete specified in the plans except for those accepted based on a Certificate of Compliance. The contractor's submittal of a mix design shall be on WSDOT Form 350-040 and shall provide a unique identification for each mix design. All Mixes, except lean concrete and commercial concrete, shall have a minimum cement content of **564 lbs**. **No concrete shall be placed** until the Engineer has reviewed the mix design.

A high range water reducer (superplasticizer) may be used in all mixes. The use shall be submitted as part of the concrete mix design. Air content shall be within the range specified in Section 6-02.3(2)A for all concrete placed above ground.

Acceptance of concrete will be based on conformance to the Contractor's mix design and the following field tests:

1. Temperature
2. Air content (for above ground)
3. Slump
4. Compressive strength at 28 days

Commercial Mix

Where concrete Class 3000 is specified for nonstructural items, the Contractor may use commercial concrete, these items include:

Culvert Headwalls	Plugging Culverts	Curbs and Gutters
Concrete Pipe Collars	Pipe Anchors	Sidewalks
Monument Cases	Luminaire Bases	Fence Post Footings
Pedestals	Cabinet Bases	Sign Post foundations
Guardrail Anchors		

The Engineer may approve other nonstructural items not listed for use as commercial concrete. Commercial class concrete shall **not** be used for structural items such as:

Bridges	Retaining Walls	Box culverts
High Mast Luminaires	Cantilever Signs	Sign Bridges
Mast Arm Traffic Signals		

Commercial concrete will be accepted based on a Certificate of Compliance (Concrete Delivery Ticket) provided by the supplier. It is advised that as the inspector collects the Certificate of Compliance, they do a visual inspection of the concrete. Visual inspection should verify that the items listed on the delivery ticket are included in the mix.

Commercial concrete placed above ground line shall be air entrained and shall have an air content within the range specified in Section 6-02.3(2)B. It is recommended that the inspectors perform air content testing sufficient to ensure that the concrete air content is in compliance.

Commercial class concrete shall conform to the following:

- Specified compressive strength at 28 days, min. 3000 psi.
- If commercial concrete is used for sidewalks, curbs, and gutters, it shall have the minimum cementitious material content specified in Section 6-02.3(2)B and shall be air entrained.
- Acceptance of Commercial is by Certified Concrete Delivery Ticket.
- The making of Concrete cylinders is not required.

Certificate of Compliance (Standard Specification 6-02.3(5)B)

A certification of compliance verifies the concrete delivered is in compliance with the mix design. A Certificate of Compliance shall be completed for each load of concrete delivered to the project. The concrete producer may provide the above information on their own form or use the WSDOT printed forms 450-001.

Please take note; on the example on the following page the tester recorded important information on the ticket like test results, water added and revolutions. The only thing missing is the name of the tester.

Section 6-02.3(5)B lists all of the items that need to appear on a Certified Concrete Delivery Ticket. For commercial concrete a minimum of batching facility, date, and quantity is all that is required.

TA 2433
6/23/03
EW

Cem Conc Barrier Curb & Gutter
Item 71 Group 3

Hood River Sand & Gravel

699+00 – 700+80.

Please remit to: Hood River Sand & Gravel
2630 Old Columbia River Dr.
Hood River, Oregon 97031
(541) 386-1400

Sold to:
HILDEBRAND CONCRETE CONST.
VANCOUVER WA 98682

Ship to:
BINGEN WA
VINE STREET -NORTH SIDE- HEAD EAST

Time	Formula	Load Size	Yards Ordered		Driver/Truck		Plant/Transaction
13:56:52	3461WC	9.00 yd	54.00 yd		JG 39		
Date		**Load #**	**Yard Del**	**Batch #**	**Water Trim**	**Slump**	**Ticket Number**
06-23-03		Today 6	54.00 yd	16737	0/yd -4.0	1.25 in	24968

WARNING
IRRITATING TO THE SKIN AND EYES
Contains Portland Cement. Wear rubber boots and gloves. PROLONGED CONTACT may cause burns. Avoid contact with eyes and prolonged contact with skin. In case of contact with skin or eyes, flush thoroughly with water. If irritation persists, get medical attention. KEEP CHILDREN AWAY.

Concrete is a perishable commodity and becomes the property of the purchaser upon leaving the plant. Any changes or cancellation of original instructions must be telephoned to the office before loading starts

The undersigned promises to pay all costs, including reasonable attorney's fees, incurred in collecting any sums owed.

All accounts not paid within 30 days of delivery will bear interest at the rate of 18% annum.

Not responsible for reactive aggregate or color quality. No claim allowed unless made at time material is delivered.

A $20.00 service charge and loss of the cash discount will be collected on all returned checks.

Excess delay item charged is $60.00/hr.

See reverse for additional terms & conditions.

PROPERTY DAMAGE RELEASE
(TO BE SIGNED IF DELIVERY TO BE MADE INSIDE CURB LINE)

Dear Customer - The driver of this truck in presenting this RELEASE to you for your signature is one of the opinion that the size and weight of his truck may possibly cause damage to the premises and/or adjacent property if he places the material in this load where you desire it. It is our wish to help you iv every way that we can, but in order to do this the driver is requesting that you sign this RELEASE relieving him and this supplier from any responsibility from any damage that may occur to the premises and/or property, buildings, sidewalks, drive-ways, curbs, etc. by the delivery of this material, and that you also agree to help him remove mud form the wheels of his vehicle so that he will not litter the public street. Further, as additional consideration, the undersigned agrees to indemnity and hold harmless the driver of this truck and this supplier for any and all damage to the premises and/or adjacent property which may be claimed by anyone to have arisen out of delivery of this order.

X _____

Excessive Water is Detrimental to Concrete Performance
H_2o Added by Request/Authorized by
5+2+2 Gal X _____

Weighmaster
ALAN SCHWELLER

Notice: My signature below indicates that I have read the health warning notice and supplier will not be responsible for any damage caused when delivering inside curb line.

Load Received by:
X Larry

Quantity	Code	Description	Unit Price	Extended Price
9.00	3461WC	3000-WDOT CONN CURB		

REV 162

Time: 31 mins
Revs: 162
H_2O+: 9 Gal
Air: 4.8%
Slump: 1"
Temp: 79° F

Returned to Plant	Left Job	Finish Unloading	Delay/Explanation/Cylinder Test Taken	Time Allowed
		2:52	1. Job Not Ready 6. Truck Broke Down 2. Slow Pour on Pump 7. Accident 3. Truck Ahead on Job 8. Citation 4. Contractor Broke Down 9. Other 5. Added Water	
Left Plant	**Arrived Job**	**Start Unloading**		**Time Due**
13:56:50	2:18	2:21		
Total Round Trip	**Total at Job**	**Unloading Time**		**Delay Time**

Additional Charge 1 _____
Additional Charge 2 _____
GRAND TOTAL ▶

Batch size 9.00 yd 3461WC
Ticket No. 24968

-Material-	-Indication-	- AVDP EQU -	- Targets -	-% Tol-	WatFree	%Moist
SAND	12800 lb	12800 lb	12880 lb	-0.6	372.8	3.00
3/4 ROCK	15920 lb	15920 lb	16040 lb	-0.7	0.0	0.00
CEMENT	4610 lb	4610 lb	4580 lb	0.7*		
FLYASH	480 lb	480 lb	500 lb	-4.0		
WATER	186 G	186 G	188 G	-1.1	1552.2	
AIR	57 fl.oz	57 fl.oz	56 fl.oz	1.8		

DryAggs: 28347 lb
Cems: 5090 lb
Waters: 1925 lb
Total: 35362 lb
Wat/Cem:
Add:

14:01:56 06-23-03
Bottles Empty

	Start	End
CEM	0	0 lb

Part 3

Preparation and Set-Up

Reference and Approvals Check List

1. Special Provisions or Amendments
   - Unique mix designs
   - Special gradations

   } Project Specific

2. Contract Plans

   Class of concrete for structures

   Look at your bridge plans. The class of concrete can be found in several places. Read the General Notes and Approximate Quantities.

3. Standard Specifications and Construction Manual
   - Section 5, 6, and 9

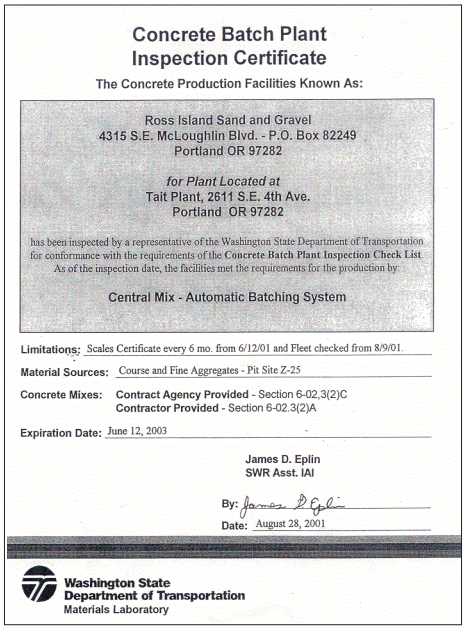
4. Material Approvals
   - Aggregates source approved
   - Cement source approved
   - Admixtures approved
   - Flyash source approved

5. Approved Mix Design
   - Check that it is the correct mix design and that it is complete.

6. Plant Approval, accomplished by either National Ready Mix Concrete Association (NRMCA) or Regional Materials Engineer *(See figure 1)* is good for two years. The inspection checks:
   - Storage and handling of cement
   - Protection of admixtures from freezing
   - Weigh batches protected from wind
   - Accuracy of weighing equipment
   - Delivery fleet

   The inspector is responsible for letting the Materials Lab know the plant needs inspecting before concrete is placed. Give them plenty of time to schedule the inspection so they can work it into their schedules.

   Do not wait until the last minute!



Concrete Batch Plant Inspection Certificate

The Concrete Production Facilities Known As:

Ross Island Sand and Gravel
4315 S.E. McLoughlin Blvd. - P.O. Box 82249
Portland OR 97282

for Plant Located at
Tait Plant, 2611 S.E. 4th Ave.
Portland OR 97282

has been inspected by a representative of the Washington State Department of Transportation for conformance with the requirements of the **Concrete Batch Plant Inspection Check List**. As of the inspection date, the facilities met the requirements for the production by:

Central Mix - Automatic Batching System

Limitations: Scales Certificate every 6 mo. from 6/12/01 and Fleet checked from 8/9/01.

Material Sources: Course and Fine Aggregates - Pit Site Z-25

Concrete Mixes: **Contract Agency Provided** - Section 6-02,3(2)C
Contractor Provided - Section 6-02.3(2)A

Expiration Date: June 12, 2003

James D. Eplin
SWR Asst. IAI

By: James D. Eplin

Date: August 28, 2001

Washington State Department of Transportation
Materials Laboratory

Figure 1

7. Any time a truck comes on the jobsite, you can inspect it. Look to see that the truck has a legible data plate and check the mixing capacity. Also check the following items on the truck:
   - Water meter/sight glass
   - Rev counter
   - Fins

Data Plate *Sight Glass* *Rev Counter*

The agitation and mixing speeds are shown on the plate in the truck. If the plate is not legible the contractor can get new ones from the manufacturer.

The red ball in the site glass gauge should go down as the water is added into the mixer.

The revolutions counter may be located in the truck's cab, ask permission from the driver before looking into the cab. The inspector must physically see the counter.

As for fins, the inspector should occasionally look for build up or wear. Look for lumps in the mix this may indicate wear or concrete buildup on the fins.

Equipment Check List

Always make sure you have the equipment needed to do the job! Here is a checklist to help you.

1. Wheelbarrow
2. Shovel
3. Level
4. Wedges
5. Work platform (approximately 2 feet · 2 feet or larger dense 3/4 inches plywood)
6. Rags
7. Water Bucket
8. Measuring Tape
9. Clip Board
10. Calculator
11. Concrete Thermometer (with current verification tag)
12. Plastic or Burlap cover for Wheelbarrow
13. Air Pot (with current verification tag)
14. Rubber Mallet
15. Slump Cone (with current verification tag)
16. Flat Metal Bar 18 inches · 1 inches · 1/8 inches

17. 5/8 inch diameter rod for the 6-inch concrete cylinders and 3/8 inch diameter rod for the 4 inch concrete cylinders
18. Cylinder Molds

Remember, always keep your equipment clean!

Required Information and Forms

The following information must be present on the job at the time of placement:

1. Mix Design – Used to verify components meet tolerances
2. Certification of Compliance
3. Mill Test Certification number on Certification of Compliance and mill certification

Test Site Preparation and Pre-pour Discussion

Find out the information below from your supervisor or the contractor well in advance of the pour:

1. Pour Time
2. Pour Location
3. Size of Pour
4. Mix Design
5. Type of Placement and Point of Acceptance (*Standard Specification* 6-02.3(5)E)
   - From the chute of the truck
   - From a concrete bucket
   - From a pump
6. Location of Cylinder Curing Box and Test Site
   - The test site must be level and able to support the tester (Picture 1)
   - Get your equipment set up and ready to go prior to the trucks arriving on the job.
   - Do not set up where you are going to hinder the contractor's operations.
   - You should be close enough so that it is relatively easy to obtain and transport your sample to your test location.

Picture 1

Know the lines of communication:

- Who will you give the test results to?
- Who is the designated responsible person for the prime contractor?

Know your level of authority:

- Can you accept or reject the mix?

Communicate!

Part 4

Mix Delivery

Truck Arrival

Contractor's Responsibilities (Standard Specification 6-02.3(4)A)

- For transit-mixed concrete, the mixing time in the transit mixer shall be a minimum of 70 revolutions at the mixing speed designated by the manufacturer of the mixer. Following mixing, the concrete in the transit mixer may be agitated at the manufacturer's designated agitation speed. A maximum of 320 revolution (total of mixing and agitation) will be permitted prior to discharge.
- Central-mixed concrete, transported by truck mixer/agitator, shall not undergo more than 250 revolutions of the drum or blades before beginning discharging.
- Contractor may make adjustments prior to turning over the certification of compliance (make certain any adjustments are noted and documented). When water or admixtures are added after the load is initially mixed, an additional 30 revolutions will be required at the recommended mixing speed.
- The contractor may reject a load prior to sampling or use.
- Once the load has been adjusted and the contractor is ready to have the material tested, collect the certificate of compliance.

Inspector's Responsibilities

- The certificate of compliance has to be signed by a responsible representative of the producer other than the driver, *Standard Specification* 6-02.3(5)B.
- Verify approved mix design weights with actual batch weights on the certificate of compliance, *Standard Specification* 6-02.3(5)C:
  - Aggregate weights shall conform within 2 percent of the weights for coarse or fine aggregate.
  - Total cementitious material weight shall conform within 1 percent of the mix design. If the total cementitious material is made up of different components, these component weights shall be within the following tolerances.
    - Portland cement weight within 1 percent
    - Fly ash within 5 percent
    - Microsilica weight within 10 percent
  - Water shall not exceed the maximum water specified in the mix design.
- For each project, at least biannually, or as required, the engineer will examine mixers and agitators to check for any buildup or hardened concrete or worn blades, *Standard Specification* 6-02.3(4)A.
- You may find using a form similar to the one on the next page useful when comparing Design with actual batched weights.

DESIGN WEIGHTS VS BATCH WEIGHTS

CONTRACT NO.	SUPPLIER		Date
CLASS CONCRETE	MIX ID NO.	MAX W/C RATIO	1
ITEM NO.	LOCATION		

APPROVED MIX DESIGN WEIGHTS (Dry)

(Weight per Cubic Yard) **Water weighs 8.34 lbs/gal**

CEMENT WT.	Lbs	+/- 1% =	Lbs to	Lbs	2
FLY ASH WT.	Lbs	+/- 5% =	Lbs to	Lbs	3
TOTAL CEM.	Lbs	+/- 1% =	Lbs to	Lbs	4
CRS. AGG. WT.	Lbs				
CRS. AGG. WT.	Lbs				
CRS. AGG. WT.	Lbs				
TOTAL COARSE	Lbs				
AGG. WEIGHT	Lbs	+/- 2% =	Lbs to	Lbs	5
SAND WT.	Lbs	+/- 2% =	Lbs to	Lbs	6

TIME	TRUCK NO.	TICKET NO.
CRS. AGG. %Moist.	SAND %Moist.	YDS BATCHED

ACTUAL BATCH WEIGHTS

(Weight per Cubic Yard)

Cement WT.	Lbs	2
Fly Ash WT.	Lbs	3
Total Cement	Lbs	4

Crs. Agg. WT.	Lbs	
Crs. Agg. WT.	Lbs	
Crs. Agg. WT.	Lbs	
Total Crs Agg. WT.	Lbs	5

Sand WT.	Lbs	6

Water Batched	Lbs
Free moisture Crs Agg.	Lbs
Free moisture Sand	Lbs
Water Added	Lbs
Total Water	Lbs

Record the dry aggregate weight.

Dividing the batch weight by 1+ percent of moisture listed on the ticket will provide the required dry weight. The difference between the batch weight and the dry weight is the weight of the free moisture.

Gal/CY **x** 8.34 Lbs/Gal

Water / Cement Ratio = _____ 1

Calculated By: _____

Temperature and Time for Placement (Standard Specification 6-02.3(4)D)

Concrete temperature shall remain between 55 F and 90 F while it is being placed.

The batch of concrete shall be discharged:

- $1\frac{1}{2}$ hour after the cement is added to the concrete.
- $1\frac{3}{4}$ hour if the temperature of the concrete being placed is less than 75 F.
- 2 hours with the approval of the Engineer and as long as the concrete being placed is below 75 F.

Point of Acceptance (Standard Specification 6-02.3(5)E)

Determination of concrete properties for acceptance will be based on samples taken as follows:

<u>Bridge Decks, Overlays and Barrier:</u>

At the Point of Discharge

<u>All other Placements:</u>

At the Truck Discharge

Once the Contractor has turned over the concrete for acceptance testing, no more mix adjustments will be allowed. The concrete will either be accepted or rejected.

Part 5

Testing

Sampling Fresh Concrete
(WAQTC TM2) and WSDOT Test Method 716

Sample Frequency (Standard Specification 6-02.3(5)G)

Sampling and testing will be performed before concrete placement from the first truckload. Concrete shall not be placed until tests for slump, temperature, and entrained air (if applicable) have been completed, and the results indicate that the concrete is within acceptable limits. Sampling and testing will continue for each load until two successive loads meet all applicable acceptance test requirements.

After the initial acceptance testing, testing frequency may decrease to one for every five-truck-loads. Loads to be sampled will be selected in accordance with the random selection process outlined in WAQTC TM2, and FOP for WSDOT Test Method 716.

Sampling and testing for a placement of one class of concrete consisting of 50 CY or less will be as listed above, except:

Sampling and testing will continue until one load meets all of the applicable acceptance requirements, and

After one set of tests indicates that the concrete is within specified limits, the remaining concrete to be placed may be accepted by visual inspection.

Example:

Using an acceptable random number program from a hand held calculator, the last digit for a license plate or other acceptable means, determine a random number.

For this example the random number selected is “37.” Enter the table at (37) and the corresponding four-digit number 0.829, this is the factor.

Based on the delivery of 10 cubic yard loads to the project. This would be adjusted by the quantity of concrete actually being delivered per load.

Next five trucks loads = 10 CY x 5 = 50 Cy

50 CY x 0.829 = 41.45 CY to be sampled

Therefore the sample will be taken from the truck containing the 41st CY. After approximately one cubic yard of concrete has been discharged the sample should be taken. This is actually the seventh truckload delivered to the project this day as the first two truckloads were sampled before the random selection process started. The process would continue for the next sample using “38” then “39” etc. For the next day’s concrete delivery and placement a new random number would be selected and the process repeated.

Where Contractor QC testing is being used for acceptance, Agency QA or Verification sampling will be done on a random basis using an independently determined random selection process. The QC and QA tests should not normally be run from the same sample, only when dictated by the independent random sample selection process.

Table of Random Numbers

X	X	X	X	X
(1)0.186	(21)0.256	(41)0.201	(61)0.508	(81)0.431
(2)0.584	(22)0.753	(42)0.699	(62)0.884	(82)0.509
(3)0.965	(23)0.108	(43)0.785	(63)0.648	(83)0.962
(4)0.044	(24)0.626	(44)0.874	(64)0.398	(84)0.315
(5)0.840	(25)0.885	(45)0.604	(65)0.142	(85)0.721
(6)0.381	(26)0.418	(46)0.087	(66)0.962	(86)0.637
(7)0.756	(27)0.320	(47)0.334	(67)0.516	(87)0.056
(8)0.586	(28)0.098	(48)0.189	(68)0.615	(88)0.905
(9)0.480	(29)0.791	(49)0.777	(69)0.226	(89)0.195
(10)0.101	(30)0.717	(50)0.704	(70)0.881	(90)0.981
(11)0.282	(31)0.868	(51)0.946	(71)0.369	(91)0.600
(12)0.957	(32)0.583	(52)0.426	(72)0.001	(92)0.044
(13)0.377	(33)0.385	(53)0.266	(73)0.744	(93)0.433
(14)0.456	(34)0.465	(54)0.791	(74)0.229	(94)0.762
(15)0.778	(35)0.101	(55)0.711	(75)0.906	(95)0.678
(16)0.243	(36)0.285	(56)0.122	(76)0.413	(96)0.347
(17)0.578	(37)0.829	(57)0.895	(77)0.827	(97)0.274
(18)0.966	(38)0.998	(58)0.371	(78)0.984	(98)0.114
(19)0.373	(39)0.539	(59)0.221	(79)0.641	(99)0.480
(20)0.834	(40)0.060	(60)0.011	(80)0.068	(100)0.685

Once the two-digit number is selected, the corresponding four-digit number becomes the factor for determining the selection of the next sample.

Truck Mixers or Agitators

- Sample for acceptance of mix from back of truck, EXCEPT bridge decks, overlays, and barriers.
- Sample initial portion of load after minimum $^1/_2$ CY discharged.

Pump or Conveyor Placement System

- No correlation allowed.
- Acceptance of mix at point of discharge for bridge decks, overlays and barriers.
- Contractor to verify pumps water chamber does not leak water past the piston.

Sample $1^1/_2$ Times Volume Required for Test but Not Less Than 1 Cubic Foot

Protect Sample

- White plastic
- Damp burlap

Remix Sample With Shovel

Concrete Temperature (FOP for AASHTO T-309)

Equipment

- Use verified/calibrated Thermometer
  - Accurate to ± 1°F
  - Temperature range from 0 to 120°F

Procedure

Concrete

To record the temperature of the freshly mixed concrete to the nearest 1ºF, following the procedure outline in FOP AASHTO T-309

Air

- Outside air
- In shade
- Accurate
- Record

Interpreting the Results 6-02.3(4)D

- Concrete at the time of placement must be between 55° and 90°F.

Slump Test *(FOP AASHTO T-119)*

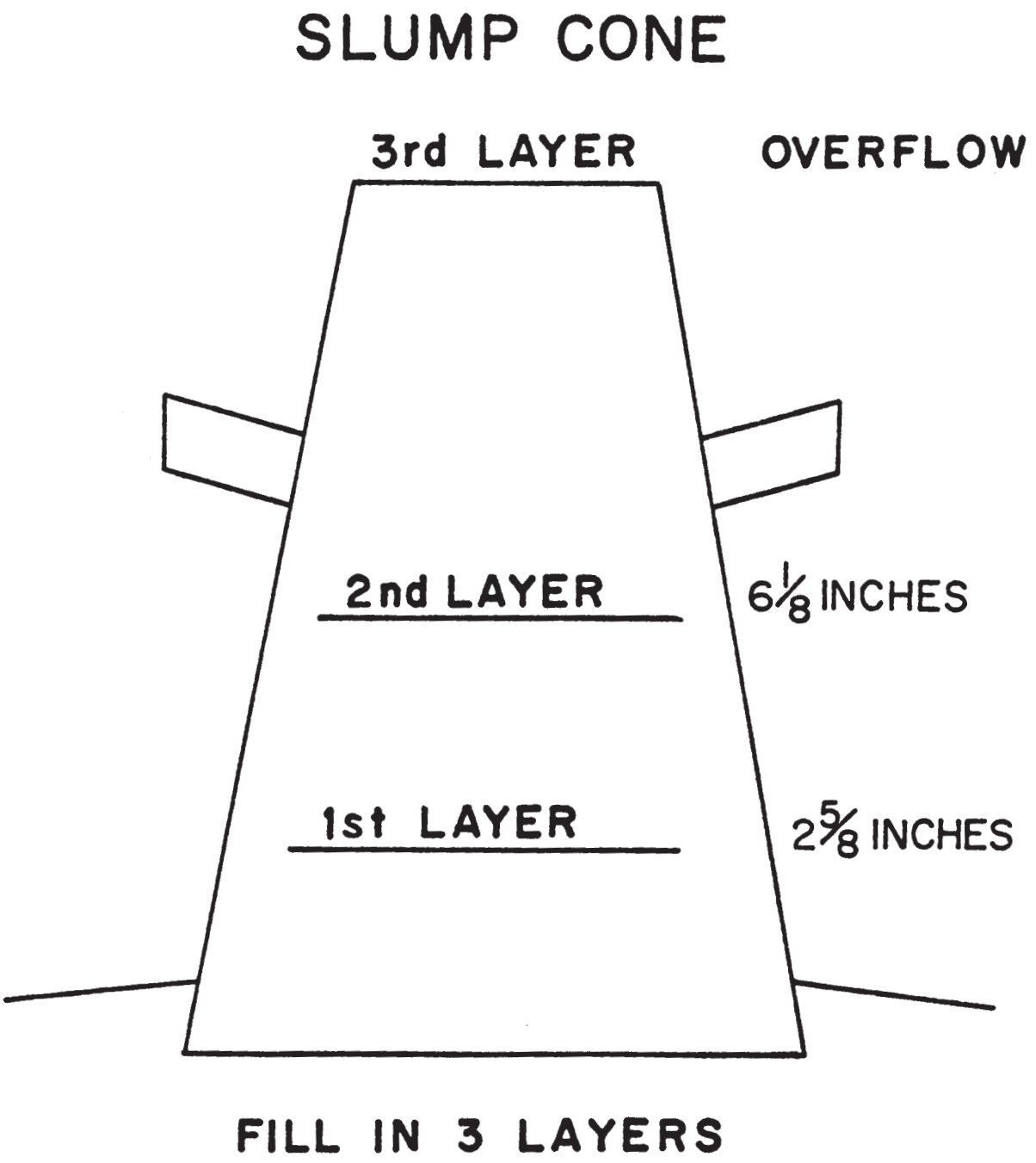
Equipment

- Stable Impervious Base (clamp-on base optional)
- Slump Cone (Verified/Calibrated)
- Rod
- Scoop
- Ruler
- Level

Procedure

This test shall be started within 5 minutes of obtaining the sample, and must be completed from start to finish within $2^{1}/_{2}$ minutes.

Dampen the cone and floor or base plate and follow the test procedure outlined in FOP AAshto T-119.


SLUMP CONE
3rd LAYER
OVERFLOW
2nd LAYER
6 1/8 INCHES
1st LAYER
2 5/8 INCHES
FILL IN 3 LAYERS

Interpreting the Results Standard Specifications 6-02.3(4)C

Specified Limits

1. Bridge Roadway Slab
   - Bridge approach slab
   - Flat slab bridge superstructure _____inches
2. Non-Vibrated Concrete _____inches
3. Shafts when using class 4000P _____inches
4. Concrete placed in curbs, gutters, and sidewalks._____inches
5. All Other Concrete _____inches

Note: If high range water reducer is used, the maximum slump listed in 1, 2, 4, and 5 above may be increased an additional 2 inches.

Concrete Outside Specified Slump Limits

Concrete outside the specified slump limits shall be rejected.

Measuring Entrained Air *(FOP AASHTO T-152)*

Air meter calibration shall be performed at six-month intervals, at the start of a project, or weekly when meter is used during concrete placement.

Equipment

- Air Meter (Verified)
- Rubber Mallet
- Scoop
- Round Rod
- Flat Bar
- Water Bottle
- Rags
- Vibrator (required for mixes with slump less than 1 inch)

Procedure

This test shall be started within 5 minutes of obtaining the sample.

Dampen the inside of the air meter and follow the test procedures outlined in FOP AASHTO T-152.

Interpreting the Results

- *Standard Specification* 6-02.3(2)A.
- The specified air content for air entrained concrete is 4.5 to 7.5 percent.
- Concrete outside the specified air content shall be rejected.

Consolidation

When performing the air test or making concrete cylinders the method of consolidation is based on the slump:

- Rod concrete with slumps greater than 3 inches.
- Rod or Vibrate concrete with slumps of 1 to 3 inches.
- Vibrate concrete with slumps less than 1 inch.

Picture 1

Picture 2

Picture 1; Note the honeycombing of the three cylinders from improper consolidation of low slump concrete.

Picture 2; After testing a cylinder to failure a large void is found near the fracture line. If these cylinders tested below specification for compressive strength, do you think the Department would have any justification to penalize the contractor?

Test Cylinders
(FOP AASHTO T-23)

Equipment

- Molds (Verified/Calibrated)
- Rod
- Scoop
- Base and Top Plates
- Flat Bars
- Level Firm Base
- Coolers or cure boxes
- Vibrator

Procedure

Molding for test cylinders shall begin within 15 minutes of obtaining the sample.

Place the mold on a level, rigid, horizontal surface free of vibrations, and follow the procedures outlined in FOP AASHTO T-23.

Storage and Shipping

Cylinders for Determining the Acceptability of Concrete (28-Day)

- Initial storage - Immediately after finishing, the specimens shall be moved to the storage place where they will remain undisturbed for the initial curing period.
- Cover specimens to prevent moisture loss.
- During initial storage, bury in moist earth or place in a cure box, free from vibrations for a period of 24 hours ± 8 hours. Specimens should be stored in a temperature range of 60° to 80° F.
- Upon completion of initial curing and within 30 minutes after removing the molds, the specimens shall be placed in a moist room or water storage tank at a temperature of 73 ± 3° F.

Transmittal Letter

- For each set of cylinders
- Test age
- Gallon Water/Cubic Yard
- Cement pounds/cubic yard
- Air entrainment
- Slump
- Curing procedure

Washington State Department of Transportation

Concrete Cylinder Transmittal

					Lab ID No.
Contract No. 6310	SR No. * 503	Section * NE 76th St. to NE 144th St.			State Lab No.
County/City Contract No. N/A	County/City * N/A		Org. Code * 444302		Region Lab No.
Mix Design No. 5010MVR	Mixing Plant Ross Island		Location North Portland		
Cement Manufacturer Tilbury	Cement Type I/II	AEA Brand MB-AE 90	WRA Brand Polyheed 997	Fine Agg Pit No. G-102	Coarse Agg Pit No. G-117
Cement LBS/CY 755	Water Gal/CY 33	AEA OZ/CY 5.7	WRA OZ/CY 30.2	Fine Agg. LBS/CY 1103	Coarse Agg. LBS/CY 1800
Other Additives N/A		% Air 5.3	Slump 3 3/4"	Tested By S. Ward	

Cyl No.	Location (Pier, Column, Curb, etc.)	Date Made	Made By	Test Age Days	Class Conc.
DW-2	Cement Concrete Approach	9-23-02	S. Ward	28	4000 PSI
DW-2A	Cement Concrete Approach	9-23-02	S. Ward	28	4000.PSI

For grout cubes, include grout manufacturer, lot number, and time made.

Remarks
Placed in cure box first 26 hours, Then transmitted to Lab

* NOT Required for WSDOT Contracts Beginning with "00"	Project Engineer (Please Print)	Submitted By	Phone
DOT Form 350-009 EF Revised 7/02	L. Hughes	D. Cotton	360-905-2084

Instructions - Concrete Cylinder Transmittal (DOT Form 350-009 EF)

Please note: Underlined items are required.

Lab ID No. - This is the next number that the project office wishes to use in order to control and track transmittals and may be preprinted on the form.

Section - This is the section of the highway on which the concrete was placed and can be found in the contract documents usually on the cover page of the contract provisions or plans.

Contract - 6-digit number assigned to contract.

F.A. No. - Federal Aid Project Number found on the front cover of plans and specifications.

SR No. - State Route number found on front cover of plans and specifications.

Org. No. - 6- digit organization code assigned to your project office.

Date - Today's date.

Avg. Temp. First 10 Days - If known, enter the average daily temperature for the first 10 days after the concrete was placed.

Mixing Plant - Enter the concrete plant at which the concrete was batched. This information can be found on the certificate of compliance delivered with the concrete.

Cement - Enter the cement manufacture. This information can be found on the certificate of compliance delivered with the concrete.

Type - Enter the type of cement. This information can be found on the certificate of compliance delivered with the concrete

Sand Source - Enter the pit from which the fine aggregates (sand) came. See certificate of compliance or the Proposed Mix Design (DOT Form 350-040).

Water - Enter the water batched and add any water which was added at the site in lb./cy or gallons/cy (kg/cubic meter or L/cubic meter). This information can be found on the certificate of compliance.

Gravel Source - Enter the pit from which the coarse aggregate (gravel) came. See certificate of compliance or the Proposed Mix Design (DOT Form 350-040).

Slump - Enter the slump results determined from WSDOT FOP for AASHTO T 119.

Cement - Enter the mass of cement in lb./cy or kg/cubic meter. See certificate of compliance.

Air Ent. Admin. Brand - Enter the air entrainment admixture manufacture. See certificate of compliance.

Amount Air Ent. Adm. - Enter the amount of air entrainment oz per cy of cement or ml per m^3 of cement. See certificate of compliance.

% Air - Enter the percent air determined from WSDOT FOP for AASHTO T 152.

Water Reducing Additive Brand - Enter the water reducing admixture manufacture. See certificate of compliance.

Amount Water Reducer - Enter the amount of water reducer oz. per cy of cement or ml per m^3 of cement.

Cyl No.- Enter the number of the cylinder cast.

Location (Pier, Column, Curb, etc.) - Enter the location in the structure where the concrete was placed.

Date Made - Enter the date the cylinder was cast.

Test Age Days - Enter the age in days at which the cylinder is to be tested. This date is normally 28 days. Consult the contract provision for any special requirements.

Class Conc. - Enter the concrete class.

Cert. No. - Enter the number on the certification delivered with the concrete.

Cyl Size - Enter the size of the cylinders being transmitted either 100 mm X 200 mm (4 in X 8 in) or 150 mm X 300 mm (6 in X 12 in).

Curing Procedure Used - Briefly described the curing procedure used.

Remarks - Enter any remarks you wish to add.

Project Engineer's Signature - Have the Project Engineer or the representative sign.

Phone - Enter the phone number to contact if someone has questions (include area code).

DOT Form 350-009
Revised 5/98

Testing for Compressive Strength With Rebound Hammer (FOP ASTM C-805)

Equipment

- Rebound hammer (Verified/Calibrated)
- Grinding stone

Procedure

Grind the area to be tested, take 10 readings and average them. See FOP ASTM C-805 for the test procedure.

Documentation

1. Record in IDR.
2. Write letter to the file for final records.
3. Write on paynote.

Part 6

Grout

Grout (Standard Specifications 6-02.3(20) and 6-02.3(26)H)

Grout used for anchor bolts, bridge bearings and tensioning ducts shall achieve a compressive strength of 4000 psi at 7 days.

Grout for anchor bolts and bridge bearings shall be a prepackage grout, mixed, placed, and cured as recommended by the manufacturer, or the grout shall be produced with the following materials:

Portland Cement Types I or II
Fine Aggregate Class 1 or Class 2
Water

Grout shall be a workable mix with flowability suitable for the intended application. Field grout cubes shall be made in accordance with WSDOT Test Method 813 for either prepackaged grout or a contractor provided mix when requested by the Engineer, but not less than one per bridge pier or one per day.

The grout used in tensioning ducts is more fluid and the Contractor shall proportion the mix to produce a grout with a flow of 11 to 20 seconds as determined by ASTM C 939, Flow of Grout for Preplaced Aggregate Concrete (Flow Cone Method).

Portland Cement Type I or II	1 Sack
Water	4.5 Gallons Maximum
Water Reducing Admixture	Mfg. Recommendation
Fly Ash (Optional)	20 Pounds Maximum

The grout shall be injected within 30 minutes after the water is added to the cement. The temperature of the surrounding concrete shall be at least 35 F until the grout cubes have a minimum compressive strength of 800 psi. The grout temperature shall not exceed 90 F during mixing or pumping. Field fabrication of grout cubes shall be made in accordance with WSDOT Test Method 813.

In addition to the required grouting equipment, the Contractor shall have standby equipment (with separate power supply) available for flushing the grout when regular equipment cannot maintain one-way flow

Test for Flow of Grout for Pre-placed-Aggregate Concrete (Flow Cone Method)(FOP ASTM C 939)

Equipment

- Flow Cone (Must be verified/calibrated each day it is used)
- Receiving Container
- Ring Stand
- Level
- Stop Watch (Verified/Calibrated)

Interpreting Resulting (Standard Specification 6-02.3(26)H)

The contractor shall proportion the mix to produce a grout with a flow of 11-20 seconds.

Fabrication of 2-Inch Cube Specimens for Compressive Strength Testing of Grouts and Mortars*(FOP WSDOT Test Method No. 813)*

Equipment

- Specimen Mold (Verified/Calibrated)
- Base Plate (Verified/Calibrated)
- Cover Plate (Verified/Calibrated)
- Tamper (Verified/Calibrated)
- Trowel (Verified/Calibrated)

Procedure

Mold three grout cubes for testing compressive strength of the mix by following the test procedures outlined in FOP WSDOT Test Method No. 813.

Appendix A

Appendix A

Effects of Excessive Water Added to Concrete

Fly Ash Technical Bulletin

Letter No. 73-1

Re: Effect of Excessive Water Added to Concrete

Concrete should contain enough water to produce a mix that has a relatively stiff consistency, which works readily and does not segregate.

Normally, concrete delivered to projects has a slump of between 3 and 4 inches. If you request the driver to add an excessive amount of water, it will affect the durability and reduce the strength of the concrete.

To verify the above statements, the following information on the subject was printed in a recent issue of the "Journal of the American Concrete Institute."

If you add only one gallon of water to a yard of properly designed 3000 psi Concrete Mix:

You increase the slump about one inch
You cut the compressive strength by as much as 200 psi
You waste the effect of 1/4 bag of cement
You increase the shrinkage potential about 10 percent
You increase the possibility of seepage through the concrete by up to 50 percent
You decrease the freeze-thaw resistance by 20 percent
You decrease the resistance to attack by de-icing salt
You lower the quality of the concrete in many other ways

Water Added Gallons per Cubic Yard	Slump Increase In Inches	Percent of Strength Reduction	Pounds Produced per Square Inch
1	1/2	4 1/2	150
1 1/2	1	6 1/2	225
2	1 1/2	8 1/2	300
3	2	13	450
4	2 1/2	17 1/2	600
4 1/2	3	19 1/2	675
5	3 1/2	21 1/2	750
6	4	26	900
7 1/2	5	33	1150
9	6	40	1400

The Customer Must Assume Responsibility for Water Added at the Job Site

POZZOLANIC

Technical BULLETIN

Number 2

FLY ASH: THE MODERN POZZOLAN

What Are Pozzolans? Pozzolans are siliceous or siliceous/aluminous materials which, when mixed with lime and water, form cementitious compounds.

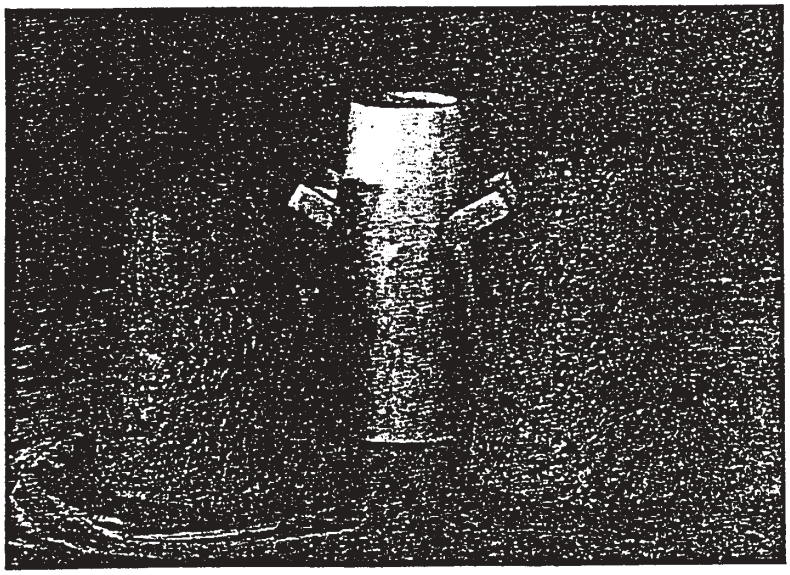
What Is Fly Ash? Fly ash is the best known – and one of the world's most commonly used – pozzolans. Physically, it is a very fine powdery material, predominately silica, with particles almost totally spherical in shape.

A Brief History: Fly ash closely resembles the volcanic ashes used in the production of the earliest known hydraulic cements some 2,300 years ago – near the small Italian town of Pozzuoli (which later gave its name to our modern day pozzolans). Predating portland cement by over 2,000 years, fly ash has significantly improved the performance of concrete throughout its history.

The Modern Pozzolan. Today's fly ash is a by-product of burning finely ground coal in electricity generating power plants. It is captured from the exhaust gases of the plants by electrostatic precipitators or bag houses which leave relatively clean air to escape from the smoke stacks. This accomplishes two objectives: the fine fly ash is prevented from polluting the ambient air and the collected material once processed becomes a valuable resource for industry.

Why Is Fly Ash Used In Concrete? Fly ash is widely used today as a cementitious material in the production of a great variety of concrete mixes. The advantages of using fly ash are detailed in Pozzolanic Technical Bulletins. Briefly they include: *Increased Compressive Strength *Increased Workability *Increased Durability *Decreased Permeability *Reduced Sulphate Attack *Decreased Bleeding and Segregation *Reduced Shrinkage *Reduced Heat of Hydration *Reduced Cement/Aggregate Reaction *Increased Flexural Strength.

The Fly Ash Advantage: The spherical shape of fly ash particles and their extreme fineness, has a beneficial effect on the workability of concrete. The shape allows the concrete to move more freely . . . and the fine particle size allows better filling of the voids. The slump test photograph shown below clearly illustrates the improved cohesion of the fly ash concrete mix.



Fly Ash Concrete **Ordinary Concrete**

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POZZOLANIC

Technical BULLETIN

WHAT IS FLY ASH?

Number 3

The American Society For Testing and Materials defines pozzolan as "a siliceous or siliceous and aluminous material which in itself possesses little or no cementitious value, but will, in finely divided form and in the presence of moisture, chemically react with calcium hydroxide at ordinary temperatures to form compounds possessing cementitious properties".

Types F and C fly ash processed and distributed by Pozzolanic are by-products of the combustion of coal in large power plants. Pozzolanic fly ash is collected in electrostatic precipitators or bag houses, then classified by precise particle size, thus assuring a uniform, quality product.

Type F fly ash is available in the largest quantities. Produced when either anthracite, bituminous or sub-bituminous coal is burned, Type F is generally low in lime, usually under seven percent, and contains a greater combination of silica, alumina and iron (greater than 70 percent) than Type C fly ash.

Type C fly ash normally comes from lignite or sub-bituminous coal. These types of coal may produce an ash with higher lime contents – generally more than 15 percent – often as high as 30 percent. This gives Type C unique self-hardening characteristics.

Where as both types of fly ash impart a wide range of qualities to many types of concrete, they differ chiefly in the following ways:

Type F

1. Most effectively moderates heat gain during concrete curing and is therefore considered an ideal replacement for some cement in mass concrete, and high strength mixes. For the same reason, Type F is the solution to a wide range of summer concreting problems.

2. Provides sulfide and sulfate resistance equal or superior to Type V cement. Type F is often recommended for use where concrete may be exposed to sulfate ions in soil and ground water.

Type C

1. Most useful in "performance" mixes, prestressed applications, and other situations where higher early strengths are important.

2. Especially useful in soil stabilization since Type C may not require the addition of lime.

For additional information or specific questions about fly ash, contact your nearest Pozzolanic technical representative.

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Technical BULLETIN

WHY USE FLY ASH?

Number 5

Concrete manufacturers, engineers, architects, developers and contractors all have an interest in specifying or using fly ash on a routine basis to improve the quality of their project and to increase their cost effectiveness.

Ready Mix Producers. A ready mix producer has several reasons for using fly ash in concrete.

1. Fly ash can compensate for fines not found in some sands and, thereby, enhance pumpability and concrete finishing.
2. Fly ash will result in a more predictable and consistent finished product which will ensure customer acceptance.
3. Fly ash offers flexibility in mix design providing a greater range of mixes – from liquid soil at 100 p.s.i. to high strength 8,000-plus p.s.i. concrete – produced by the same batch plant without exotic equipment.
4. Fly ash improves the flowability of the concrete which translates into less wear and tear on all the producer's equipment from batching facilities to trucks.
5. Fly ash enables the producer to customize designs to each customer's needs, thus providing the producer who uses it with a competitive advantage.

Engineers and Architects. Engineers and architects will find that fly ash provides the following benefits:

1. It enables them to provide the client with a superior and more durable finished concrete.
2. Fly ash produces a high strength concrete that accommodates the design of thinner sections.
3. Fly ash permits design flexibility accommodating curves, arches and other pleasing architectural effects.
4. The addition of fly ash to the mix is a built-in insurance for later-age strength gain in concrete.
5. Fly ash ensures that the concrete will qualify as a durable building material.
6. Fly ash contributes to the aesthetic appearance of the concrete.

Developers, Contractors, Owners. Fly ash concrete provides the following advantages to developers, contractors and owners:

1. The workability of fly ash concrete generally ensures that the speed of construction is faster which translates into a quicker return on investment.
2. Fly ash in the mix accommodates more creative designs.
3. Since fly ash concrete is not as vulnerable to deterioration or disintegration as rapidly as concrete without fly ash, it ensures low-maintenance buildings which will retain their value over the long-term.

Fly ash definitely enhances concrete construction and returns real benefits to every member of the building team.

For further information or specific questions about the use of fly ash, contact your nearest Pozzolanic technical representative.

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POZZOLANIC

Technical BULLETIN

CHEMICAL COMPARISON OF FLY ASH AND PORTLAND CEMENT

Number 7

The chemical composition of fly ash is very similar to that of portland cement.

The table below shows typical compound analyses for two fly ashes and a natural pozzolan (Class F Fly Ash, Class C Fly Ash and Class N - Natural) and ordinary portland cement. A glance at the table reveals:

1. The same compounds exist in fly ash and portland cement. Those of fly ash are amorphous (glassy) due to rapid cooling; those of cement are crystalline formed by slower cooling.

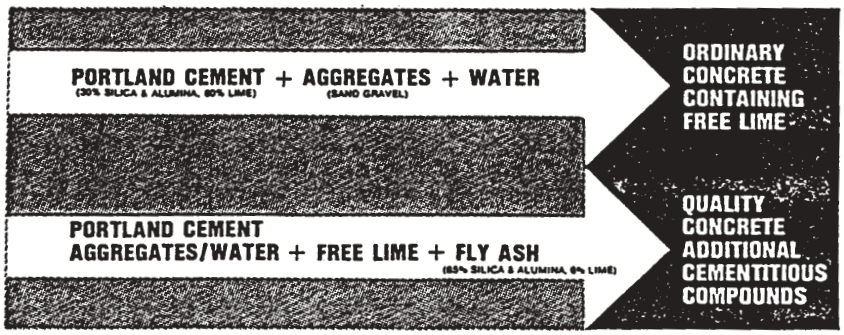
2. The major difference between fly ash and portland cement is the relative quantity of each of the different compounds. Portland cement is rich in lime (CaO) while fly ash is low. Fly ash is high in reactive silicates while portland cement has smaller amounts.

TYPICAL CHEMICAL COMPOUNDS IN POZZOLANS AND PORTLAND CEMENT

CHEMICAL COMPOUND	POZZOLAN TYPE			CEMENT
	CLASS F	CLASS C	CLASS N	
SiO	54.90	39.90	58.20	22.60
Al_2O_3	25.80	16.70	18.40	4.30
Fe_2O_3	6.90	5.80	9.30	2.40
CaO	8.70	24.30	3.30	64.40
MgO	1.80	4.60	3.90	2.10
SO_3	0.60	3.30	1.10	2.30
Na_2O & K_2O	0.60	1.30	1.10	0.60

The table illustrates the basic chemical difference. Portland cement is manufactured with CaO some of which is released in a free state during hydration. As much as 20 pounds of free lime is released during the hydration of 100 pounds of cement. This liberated lime forms the necessary ingredient for reaction with fly ash silicates to form strong and durable cementing compounds no different from those formed during hydration of ordinary portland cement.

A review of the chemistry of both materials makes it quite apparent that a blend of the two will enhance the concrete product and efficiently utilize the properties of both.



For further information or specific questions about the chemistry of fly ash, contact your nearest Pozzolanic technical representative.

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